

B-16

OPERATING INSTRUCTIONS

for

TYPE 1501-A LIGHT METER

Form 684-D



GENERAL RADIO COMPANY

CAMBRIDGE 39

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LOS ANGELES

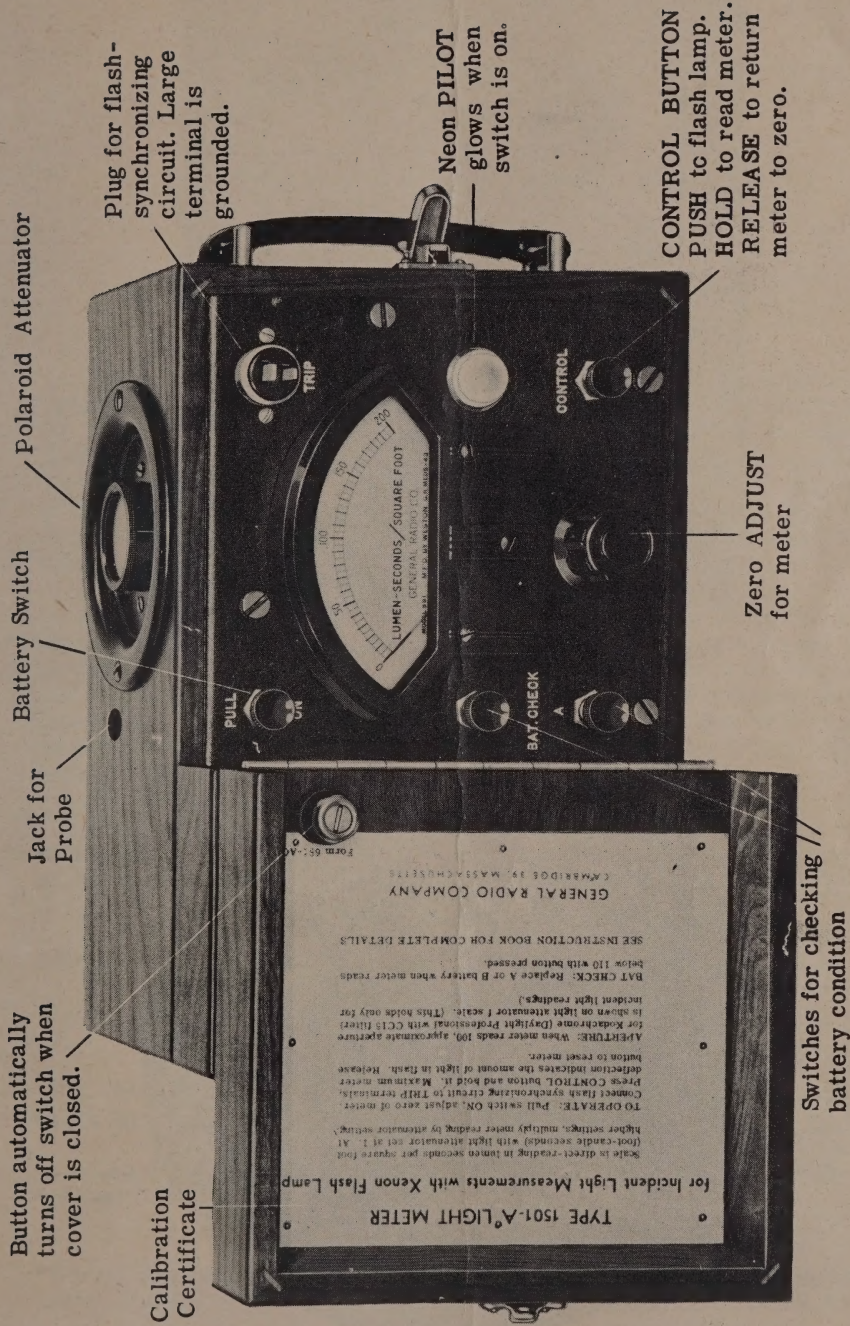


Figure 1a. General view of Type 1501-A Light Meter.



The Light Meter in a Photographic Studio.

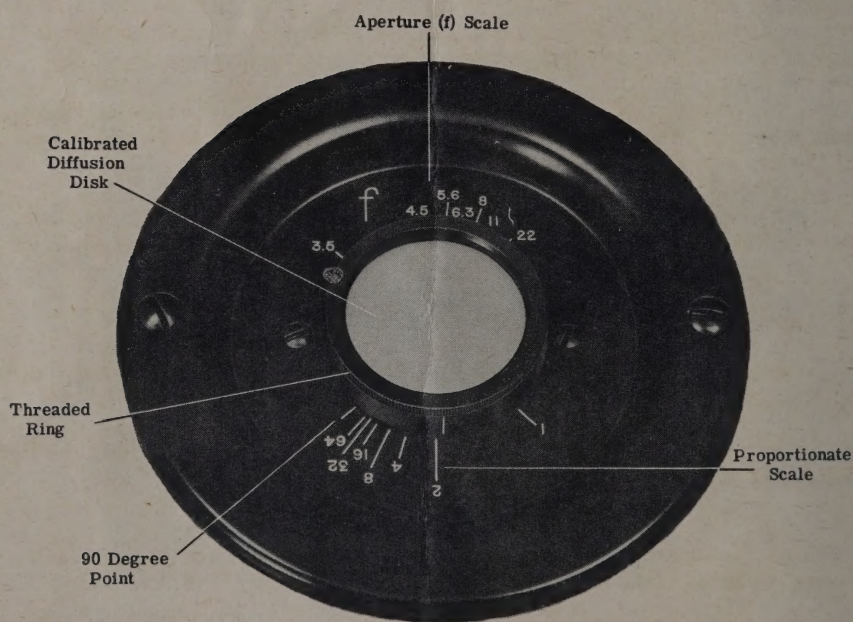


Figure 1b. Close-up of Polaroid Attenuator.

OPERATING INSTRUCTIONS

for

TYPE 1501-A LIGHT METER

INTRODUCTION - USES

The Type 1501-A Light Meter gives a reading of the total amount of light falling on a phototube through an aperture at the front of the meter. Its primary use is in photography with electric flash tubes of the xenon type (called "Speedlights", "Strob", etc.) to determine the correct camera aperture for color-film exposure.* It differs from ordinary "exposure" meters in that it is designed to sum up and indicate the total amount of light in a short flash, rather than to indicate the average level of continuous illumination.

This meter is also particularly useful in making periodic checks of electric flash tubes used in speedlights to be sure that they have not deteriorated to the point where tube replacement or servicing is desirable. A further use is in comparing the illumination produced by different xenon flash tubes. It is possible to use the meter on other types of flash units and the common chemical flash bulb, if allowance is made for the difference in spectral distribution of the emitted light.

For measuring the intensity of light reaching the film in the camera, an accessory probe (Type 1501-P1) is available which attaches to the back of the camera ground glass with rubber suction cups.

A plate (Type 1501-P2) for mounting a standard Eastman or Wollensack synchronized shutter is also available for testing chemical flash bulbs.

SECTION 1.0 OPERATION

(Note: A description of the electrical circuit and the principles upon which the meter operates will be found in Section 3.0.)

Figure 1 shows two views of the light meter - the panel, and the light aperture, with the controls and adjustments identified.

*Harold E. Edgerton, "Photographic Use of Electrical Discharge Flash-tubes", Journal of the Optical Society of America, July 1946, Vol. 36, No. 7.

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TO OPERATE THE METER

1. Pull up the ON switch. The neon pilot light will glow, and the meter will swing down scale, then return to near zero.

2. Set meter to zero with ZERO ADJUST knob. The zero may drift slightly and should be checked periodically.

3. Connect the external flash synchronizing circuit to the plug on the panel. A mating plug is provided for making these connections. The large terminal should be the ground connection.

4. Place meter at the subject position so that light from flash is directed toward the meter aperture.

Tripod mounting thread (1/4 - 20) is provided on bottom of meter.

5. Press CONTROL button and hold it down. Meter will deflect up scale, and the indication is a measure of the amount of light in the flash. Meter is reset to zero by releasing the button.

TO DETERMINE CAMERA APERTURE - INCIDENT LIGHT METHOD

Mounted in front of the aperture are two polaroid disks, one of which can be rotated with respect to the other. These act as a light attenuator, so that the amount of light admitted through the meter aperture can be adjusted.

Supplied with the meter is a diffusion disk, which mounts over the polaroid attenuator. THIS DISK MUST BE IN PLACE WHEN THE METER IS USED TO DETERMINE CAMERA APERTURES FOR COLOR PHOTOGRAPHY. This diffusion disk makes the meter scale direct reading in lumen-seconds per square foot (foot candle seconds) when the attenuator ratio is set at "1". At other values such as 8, the lumen seconds per square foot or foot candle seconds are obtained by multiplying the meter reading by the factor 8.

The following directions are for use of electric flash lamps (xenon) and daylight professional Kodachrome film, which requires about 100 foot candle seconds at f/3.5 for average subjects with direct front lighting, and corresponding greater illumination at smaller apertures (see Table I).

1. Place meter at position of subject to be photographed, with meter aperture toward the flash lamp.

2. Set polaroid attenuator to some convenient f value, say f/3.5 (corresponds to "1" on ratio scale).

3. Press control button to end of stroke.

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4. Note meter reading. This reading is in lumen-seconds per square foot (only for f/3.5 setting).

5. If meter reading is 100, f/3.5 is the correct aperture for normal subjects with professional Kodachrome. (See Table II for other color materials, and also graph on page 5.)

6. If meter reading is below 100, camera aperture for normal subjects must be larger (lower f number) as indicated in Table I. If reading is above 100, camera aperture must be small (higher f number). If the reading is 165, for instance, the correct aperture should be f/4.5; if reading is 50, aperture should be f/2.5.

7. Correct aperture for any arrangement of lights can also be determined directly by changing the attenuator setting and repeating measurements until meter reads 100. Correct aperture is then read directly from scale on the polaroid attenuator.

8. If some particular camera aperture is to be used in taking the photograph, the meter attenuator should be set to this aperture, and the lights readjusted until the meter reads 100.

A table of meter readings for average exposure for some of the commonly used color emulsions is given in Table II for f/3.5 aperture.

TABLE I*

Foot candle second required for Kodachrome (professional sheet film daylight) with 81B filter at indicated f stops.

f Camera Aperture	Meter Reading at Subject for Normal Exposure Foot Candle Seconds (Lumen-Seconds/sq. ft.)
1.0	8.13
1.4	16
2.0	32.5
2.8	64
4.0	130
4.5	165
5.6	256
6.3	326
8	520
11	986
16	2080
22	3940
32	8380

*Preliminary, subject to revision.

TABLE II*

Film	Suggested Filter For Xenon Flash	Required Meter Reading (foot candle seconds) at f/3.5; Incident Exposure and Average Subject
Kodachrome Prof. Film, Daylight Type	81-B	100
Ektachrome Prof. Film, Daylight Type	CCO5M	100
Kodachrome Daylight, 35 mm and Bantam	81-B	80
Kodacolor (Roll only)	81-B	32
Anso Tungsten [#] Color Positive	Conv. 12	32
Anso Daylight [#] Color Positive	CC44 + CC23	90

*Preliminary, subject to revision.

[#]Anso recommends the Tungsten type for xenon flash. Processing influences effective speed.

The above values of incident light for any type of film can be estimated from the Exposure Index S as follows:

$$I = \frac{CA^2}{TS} \text{ foot candles (A.S.A. Standard Z 38.2, 6. 1948)}$$

or $IT = CA^2/S \text{ foot candle seconds}$

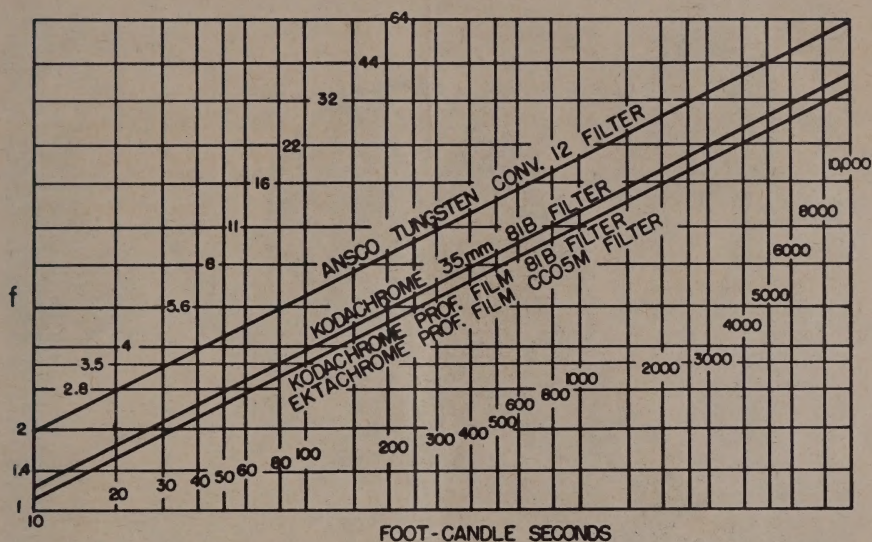
The actual incident light required is usually larger than this amount since light is lost in the filter, and extra light is needed because of the short exposure.

The use of the light meter for color photography has been described in terms of the simplest type of lighting where the lamps are grouped at or near the camera. This type of lighting is seldom used and therefore the photographer must adapt the meter to his particular type of lighting.

One system is to measure the incident light at the subject from each source separately in a direction perpendicular to the source. Experience will indicate the ratio between different sources for main and fill lamps. Many photographers use a figure of 2 to 4 between the main key light and the fill-in lamps.

For any particular lighting set-up, a hemisphere diffuser can be used to increase the acceptance angle of the meter. Calibration for this combination is made by the user so that a known meter reading corresponds to the light level suitable for a photograph.

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Convenient Graph Form Presenting Information from Tables I and II.

USE OF PROBE TO MEASURE LIGHT AT FILM SURFACE

Plug probe cord into meter case as indicated in Figure 2. Place a large white card on the subject to be photographed, and focus camera to produce sharp image of card on ground glass. Next, attach probe to ground glass over image of white card, and cover back of camera and probe with black cloth to exclude all external light. Open the lens and press control button to operate flash and note meter reading.

Be sure that the image of the white card is at least as large as the light-acceptance hole in the probe.

When using the probe always set the light attenuator to the 90° point (see Figure 1), or cover the aperture so that light will not enter the usual opening on the meter. A solid disk is furnished with the probe for this purpose.

No means of standardizing has been provided for readings taken with the probe. The user can easily determine the significance of the meter indications by making a few trial exposures. Since individual Type 1P39 phototubes may differ in sensitivity by as much as 3 to 1, two light meters, when used with the probes, will not necessarily give the same reading.

The measurement of light energy received at the ground glass is the most fundamental way to measure exposure since all factors such as aperture, lens absorption, bellows extension, etc., are included. Eventually, tables of exposure for all film materials will be available.

For other uses of light meter, see Section 4.0.

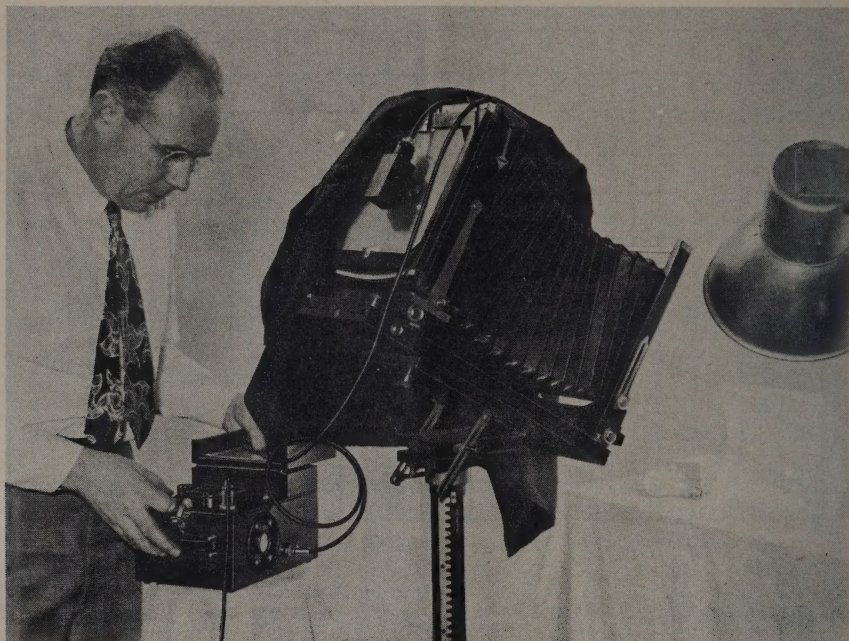


Figure 2. Light Meter with Probe Arranged to Measure Light at Camera Groundglass.

SECTION 2.0 CIRCUIT AND PRINCIPLES OF OPERATION

The electrical circuit is shown in Figure 3. Light entering the aperture on the front of the meter, after being attenuated by a pair of calibrated rotatable polaroid disks, strikes the phototube and produces an electric current proportional to the light intensity. This current is integrated, or summed up, in a capacitor, and the voltage across the capacitor is proportional to the exposure, or quantity of light received by the phototube. A vacuum-tube voltmeter indicates this capacitor voltage.

The CONTROL pushbutton performs three operations in sequence as the button is pushed: (1) the light-integrating circuit is made active; (2) the external synchronizing circuit connected to the plug on the panel is closed to actuate the electric flashbulb; (3) the phototube circuit is opened so that any continuous light impinging on the photocell will not unduly affect the meter reading, and the meter reading is held for a reasonable time if the button is held down. Circuit is reset on release of the button. A rapid push is required if the ambient light is high. A test with flash disconnected will indicate the error due to ordinary light.

Hold pushbutton in mid-position for open flash operation.

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ATTENUATOR

The attenuator consists of two polaroid disks, one of which can be rotated. Any degree of light transmission from complete transmission to almost complete extinction can be obtained. One scale is used for camera aperture settings; the other for direct measurements of illumination. Maximum extinction occurs when the indicator is set at the short un-numbered line given as the 90° point in Figure 1.

CALIBRATION

To obtain incident light per unit area received at the front of the light meter,

$U = kRW$ foot candle seconds (lumen-seconds per square foot)
(calibrated with a standard xenon flashtube)

where W = meter reading

R = multiplying factor as set on the proportionate scale on the polaroid attenuator on the front of the meter (not f numbers).

The accuracy decreases for large ratios since the angle between steps is smaller. A 20% error may be experienced for the 64 range, while lower ranges are accurate to about 5%.

k = a constant for the meter as calibrated with the output of a standard FT-214 (General Electric Company) flashtube. A calibrated diffusing disk is furnished which makes $k = 1$ so the meter is direct reading.

The diffusion disk mounts in the threaded ring on the front of the attenuator mounting. Keep diffusion disk clean for accurate results.

TIME OF FLASH

The light meter will indicate a low value of total light if the flash duration is less than about 1/10,000 second for a full-scale deflection. For readings of less than full scale, the allowable flash duration is proportionally shorter.*

FILTERS

Neutral density filters can be used to extend the scale range. Thus a 1/10 transmission filter would give a multiplying factor of 10. Neutral density filters are available from the Eastman Kodak Company and other suppliers in decimal, logarithmic, or percentage steps. The threaded ring accepts series V filters (1-3/16 inch diameter).

Recalibration for any other filter disk can be accomplished by experimentally determining k by the ratio of two readings - one with and one without the new filter that is to be used.

*Harold E. Edgerton, "Light Meter for Electric Flash Lamps", ELECTRONICS, June, 1948.

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ANGLE OF LIGHT ACCEPTANCE

The meter reading decreases 50% when the instrument is turned about 15 or 20 degrees from the lamp-subject line without the diffuser disk. The diffuser disk, which gives a $k = 1$ factor, increases the above angle to about 25 degrees.

OTHER PHOTOTUBES

The light-meter calibration is made with a specific phototube (Type 1P39) which is a vacuum-type tube with an S-4 surface. Thus, if the phototube is exchanged for other phototubes, the calibration will not hold. The S-4 surface has a peak sensitivity in the blue portion of the spectrum at 4100 Å. The sensitivity decreases from this peak to the cut-off value which is in the orange. Very little red light is measured. See curves, Figure 4.

OTHER FLASHTUBES

The phototube in the light meter will respond to the light from any kind of light source. However, the meter output cannot be expressed in lumen-seconds per square foot unless the spectral distribution is the same as the xenon flashtube that is used for calibration. All xenon flashtubes, to a first approximation, have a comparable spectral distribution and therefore the meter readings can be given in terms of lumen-seconds even if the phototube spectral sensitivity does not match that of the standard eye.

SECTION 3.0 ROUTINE MAINTENANCE

BATTERY CHECK

If the meter reads less than about 110 when either of the BATTERY CHECK buttons is pushed, that battery needs to be replaced, although the meter may operate even if the battery reads as low as 90. New batteries should give several hundred hours of continuous use. However, even without use, the batteries should be changed twice a year because of battery deterioration.

Do not leave the batteries in an instrument that is stored as the batteries may swell and leak after their expiration date is exceeded.

New batteries will read approximately as follows when BATTERY CHECK button is depressed.

- A battery - 1.5-volt, 2F Burgess or equivalent - 145 on meter
- B battery - 45-volt, XX30E Burgess or equivalent (3 required) - 135 on meter

The battery compartment is opened by removing the four screws on the top of the hinged cover.

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The B batteries should run down at the same time since they all draw the same current. However, should one battery become discharged much earlier than the other two, it is possible that the B battery reading will not be below the limit but the meter cannot be zero balanced. To find if this is the case, exchange the position of the batteries and observe if the zero position of the meter is off scale in the same direction. Another test is to measure separately the voltage across each battery with a voltmeter.

For the above reason, the B batteries should all be of the same date and condition when installed in the instrument.

LEAKAGE CHECK

Should electrical leakage currents become excessive, the meter will drift at an excessive rate. To test for the faulty element try the following procedure. First remove the probe, then cover the light input opening and depress the pushbutton to the end of its travel. If the meter drifts, the leakage is either wiring, or the switch, or grid current in the vacuum tube. Change the vacuum tube to find if the grid current is causing the drift.

If the drift occurs when the pushbutton is in the half-way position, then the leakage is due to the phototube or its circuit. Change the phototube.

If excessive drift cannot be eliminated the instrument should be returned to the Service Department at the factory.

TUBES

Phototube Type RCA1P39.

Amplifier tube, Type 1L4, must be selected after aging for low grid current, or the meter will drift when button is pushed.

Suitable 1L4 tubes are available from the General Radio Company. The calibration will not be appreciably influenced by a replacement amplifier tube, but must be checked when phototube is replaced.

STANDARDIZATION

Where the light meter is to be used in standardizing measurements, it is recommended that a standard flashtube be used for periodic calibration checks. Any xenon flashtube operated from a known capacitor at a specified voltage can be used as a standard flashtube if the duration of flash is greater than 100 microseconds. The standard flashtube used at General Radio is a General Electric FT-214 tube flashed from 100 microfarads charged to 2000 volts. With 200 watt seconds, as described, the average FT-214 will have a horizontal-candle-power-seconds output of 625 HCPS. The front of the light meter should be located 29.5 inches from the center of the flashtube to obtain a 100 foot-candle-second incident-light meter reading.

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Care must be used with a test of the above type to eliminate reflected light from objects near the standard flash bulb. Such light can easily introduce 20 percent error in the incident light received by the meter. The use of light shields and black velvet material over objects in close view is recommended.

DIFFUSION DISK

The diffusion disk should be inspected at frequent intervals to be sure that it is clean and has not deteriorated or been damaged.

SECTION 4.0 OTHER USES OF LIGHT METER

USE OF LIGHT METER TO TEST CONDITON OF FLASHTUBES

The meter, when the calibrated diffusion disk is in place, reads directly in foot-candle-seconds (lumen-seconds per square foot). Consequently, routine measurements at any convenient, fixed test distance from lamp to meter will measure the horizontal light output of the lamp directly. For direct measurements in lumen-seconds per square foot, the attenuator index should be set at 1 on the proportionate scale. Other settings indicate multiplying factors for the meter scale.

MEASUREMENT OF THE OUTPUT OF A SOURCE AT A DISTANCE

The output in beam candlepower seconds of a source can be calculated from the meter reading, the attenuator setting, and the distance between source and meter:

$$\text{Beam CPS} = kWRD^2$$

where $k = 1$, when diffusion disk is in place, W = meter reading, R = attenuator setting (proportional scale), and D = distance in feet between lamp and meter.

MEASUREMENT OF THE TOTAL OUTPUT OF A BARE LAMP WITHOUT A REFLECTOR

If the light output is constant in all directions, the total output in lumen seconds is obtained by multiplying the candle-power seconds by 4π . For most tubes this factor is about 10 instead of 4π since the base of the lamp absorbs some of the output and because the lamp is non-symmetrical.

Total output in lumen seconds, Q , = $\text{CPS} \times 10 = \text{meter reading} \times \text{attenuator} \times D^2 \times 10$ (approximately, for average lamp).

$$Q = kWRD^2 \times 10$$

A more accurate method is the use of a large integrating sphere for comparing the total light with the total light from a standard flashtube.

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CHEMICAL FLASH BULBS

The TRIP terminals can be used to fire the ordinary chemical flash bulb if a battery is wired in series with the TRIP terminals and the bulb. A fairly slow push on the button will enable a reading to be made of the entire light output. If the pushbutton is pushed too fast, the circuit of the photo electric tube might be opened before the chemical flash bulb has gone out and thus, the meter will not integrate the entire output. The amount of light from usual lighting sources does not influence the reading even for a fairly long push. However, it is easy to measure the error for any case simply by reading the meter with the type of push that is to be used for the flash measurement.

The meter is not calibrated for the light from chemical flash bulbs since the color temperature is different than that of the xenon flashtube, but comparison readings can be made between flash bulbs of the same type.

ACCESSORY SHUTTER WITH TRIP CONTACTS

A plate (Type 1501-P2) mounting a standard Eastman, Wollensack, or other synchronized shutter can be supplied, at extra cost, for testing chemical flash bulbs. The shutter contacts are arranged to give the conventional 5 or 20 millisecond lead time before the shutter leaves open. Also the shutter open time can be adjusted over a considerable range of time corresponding to values used in photography.

Comparison of the "open flash" light from a chemical flash bulb can in this way be made with light from "synchronized" shutter combinations.

It must be remembered that the pushbutton must be in the mid-position of the push when the shutter operates, otherwise a reading will not be made. Some care is required to hold the pushbutton at the right point. Usually the meter reading will drift slowly when the switch is right; a coin such as a penny can be used as a shim under the pushbutton edge.

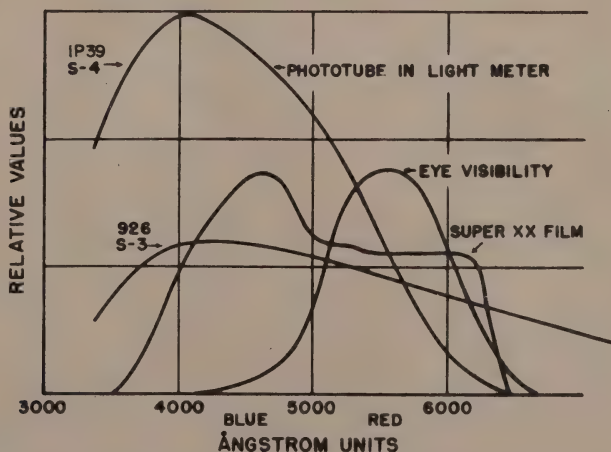


Figure 4. Spectral Sensitivity Curves.

RESISTORS

R1 =	3.3 K Ohms		POSW-1
R2 =	26 K Ohms		POSC-11
R3 =	220 K Ohms	±10%	REC-21BF
R4 =	2.2 K Ohms	±10%	REC-21BF
R5 =	2.7 K Ohms	±10%	REC-21BF
R6 =	470 K Ohms	±10%	REC-21BF
R7 =	4.7 K Ohms	±10%	REC-21BF
R8 =	510 K Ohms	± 5%	REC-21BF
R9 =	5.1 K Ohms	± 5%	REC-21BF
R10 =	1 Megohm	±10%	REC-21BF

CONDENSERS

C1 =	0.05 μ f	±10%	COP-9-2
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MISCELLANEOUS

M1 =	Meter		MEDS-43
P1 =	Pilot Light G.E. NE-51	(G.R. 2LAG-2)	
SO-1 =	Socket		CDMS-15

S1 =	Switch		SWP-14
S2 =	Switch		SWP-12
S3 =	Switch		SWP-13
S4 =	Switch		SWP-13

PL1 =	Plug		CDMP-14-2
PL2 =	Plug		CDMP-1424
PL3 =	Plug		CDMP-1424
PL4 =	Plug		CDMP-1424
PL5 =	Plug		CDMP-1425

Battery 45v. Burgess. #XX30E
 Battery 1.5v. Burgess. #2F

TUBES
V1 = 1P39
V2 = 1L4

SEQUENCE OF SWITCH OPERATION ON:

S-1 Normal position 1-2 open, 2/3 closed, 4-5 closed.
 As plunger is pressed, 2 & 3 must open before 1 & 2 closes and
 1 & 2 must close before 4 & 5 opens, bend #6 so #5 does not
 touch in maximum position.

S-2 When plunger is pressed to open switch, contacts 1 & 2
 must open first to break "A" battery connection ahead of
 "B" battery connections.

#20 POLYETHYLENE

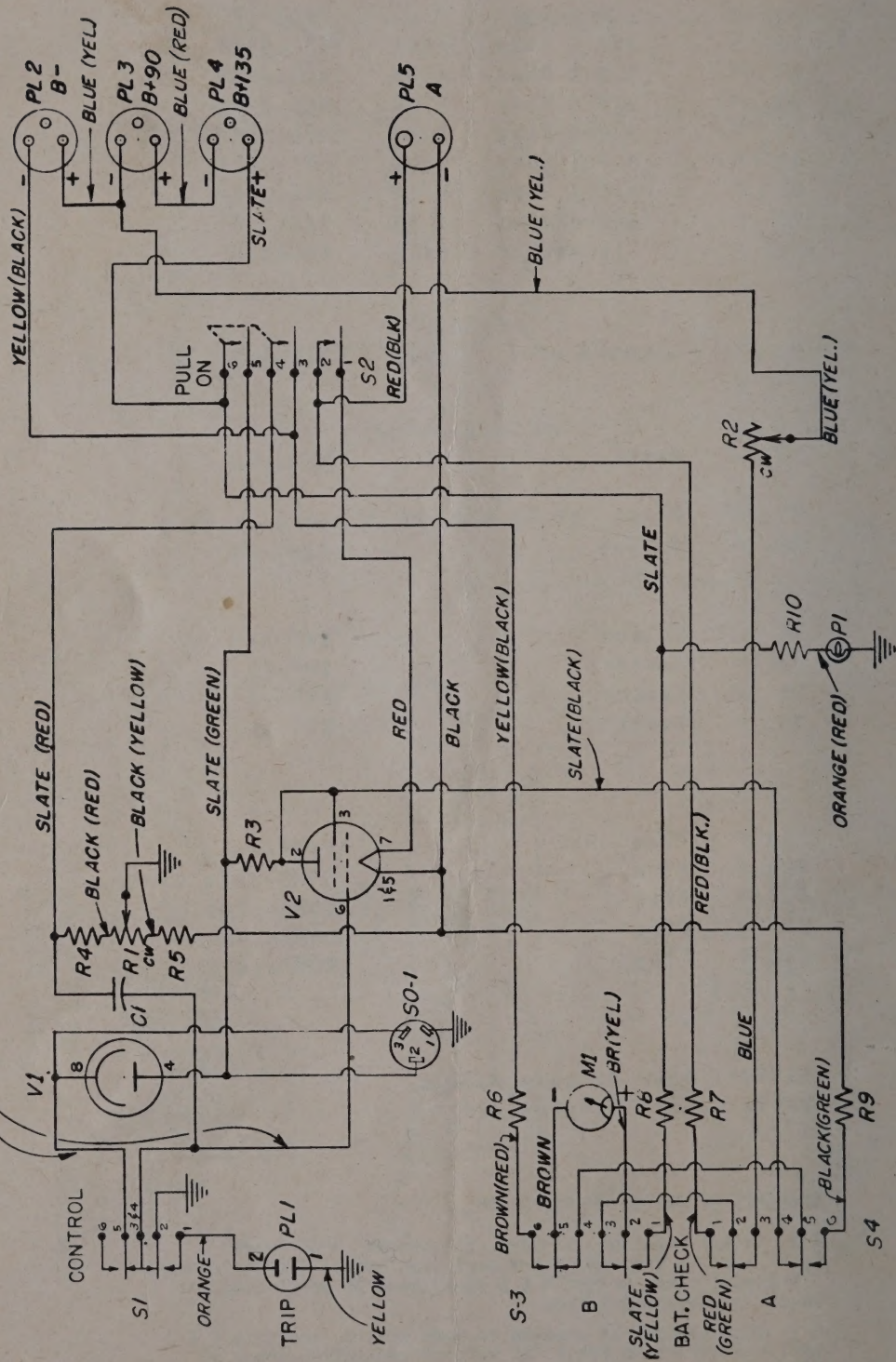


Figure 3b. Complete Wiring Diagram of the Light Meter.

